Capacity-sharing in logistics solutions: A new pathway towards sustainability

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ABSTRACT

The sharing economy concept – an extension of the internet of things concept - has contributed to the emergence of a new paradigm of freight transportation, where the main players are puppet masters in controlling data and not only physical assets. This new economic model is based on the use of technology to allow companies, citizens and other actors to share and monetize the excess capacity of their assets (vehicles, houses, parking spaces, etc.). The potential effects of this model are difficult to quantify, but it has been ventured that this new economic relationship will yield greater efficiency to businesses across the world, especially in the supply chain and city logistics processes. Such prospect relies on the fact that it is based on the provision of opportunities to monetize resources that already exist, instead of creating additional infrastructures in order to meet the demand. In this context, the application of the shared economy model to logistics brings up concepts of logistics sharing capacity. Logistics sharing capacity assumes the access and sharing of operational capabilities, either by vehicle sharing, by vehicle capacity sharing, sharing warehousing or infrastructure sharing.

The potential of logistic sharing solutions and respective transport capabilities to reduce emissions and mitigate the transport sector's impacts on climate change comes along with benefits to companies with the reduction of overall operating expenses, by reducing transport costs per kilogram and cutting maintenance and personnel costs, as fewer assets are needed. To the public sector, the benefits are still mostly felt in terms of environment as a consequence of the more effective use of resources. In fact, in spite the recent emergence of logistics sharing solutions, the topic has not been sufficiently explored under a perspective that: a) highlights the role that municipalities can play to benefit from the sharing economy model and; b) analyzes case studies in which municipalities provide owned assets to be shared by logistics players.

The objective of this paper is to contribute to reduce that hiatus on research by assessing the impact of logistic sharing solutions under a public good perspective. Therefore, the paper analyses the potential impacts of promoting the shared usage of logistic parking infrastructure owned by public authorities. As a demonstration of that potential, the possible benefits of sharing parking spaces dedicated to urban logistics operations by other users were studied, in particular the parents taking children to kindergartens located in the area. The paper is supported by a case study carried out in a Portuguese city and the effects are quantified in metrics of transport performance, energy and environmental criteria. The scenario is compared to a baseline situation (BAU) and results show significant reductions in delay times, travel times, queue lengths and stopped times and increases in average speeds. Also, fuel consumption and emissions present considerable reductions in the tested scenario. As a result, the paper concludes that municipalities can take advantage of a sharing economy context, in which logistics sharing solutions can be exploited, by using their assets in a joint and more effective way. Those benefits are translated into the reduction of externalities and improvement of the quality of life in the city and, therefore, municipalities benefit from playing an active role in the emergent context of a sharing economy.

1. Context

The emerging sharing economy model is based on the use of technology to allow companies, citizens and other actors to share and monetize the excess capacity of their assets (vehicles, houses, parking spaces, etc.). The potential effects of this model are hard to quantify, but it has been ventured that this new economic relationship will yield greater efficiency to businesses across the world. While some of these sharing models might have emerged from a need for frugal spending after the global economic recession of 2008, their success was also driven by a growing environmental consciousness combined with the

ubiquity of Internet and associated information and communication technologies which make sharing possible at large scale (Cohen, 2014). Together, these developments have started to challenge traditional thinking on how resources can and should be offered and consumed, supporting arguments that incremental improvements in our existing production and consumption systems are insufficient to transform the global economy toward sustainability (Lovins and Cohen, 2011; Stead and Stead, 2013). Boosters claim the new technologies will yield utopian outcomes – efficiency and even lower carbon footprints – which creates a great prospect about the potential sustainability benefits associated with such sharing economies in the context of the increasing

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urbanization that many cities are experiencing.

Due to its relative novelty, research on the relationship between business and sustainability theory in the context of a sharing economy is still scarce (Daunorienė et al., 2015). More specifically, despite the growing demand and opportunity for sustainable mobility solutions enabled by the private sector, there is a surprising flaw of research in the public policy and management disciplines regarding factors influencing the adoption and success or failure of collaborations between the private sector and cities in solving urban sustainability challenges in the context of a sharing economy (Alexandrescu, 2014).

Accordingly, the aim of this research is to assess the impact of logistic sharing solutions under a public good perspective, by estimating the impacts of sharing logistics parking infrastructure owned by public authorities, in a context of an emergent sharing economy. In this paper, a real case is explored focusing on public logistics parking spaces that can be shared by logistic players and other users, with dedicated time windows for each group.

2. Sharing economy as a path to more sustainable cities and logistics

The term 'sharing economy' emerged during the global financial crisis that started in 2008, representing a process through which an individual or organization harnesses the excess of capacity for a more efficient use. The concept has been either applied to tangible goods in an attempt of rationalization of resources and minimization of impacts, or applied to the sharing of intangible goods, such as information, opinions, images and ideas (Belk, 2007, 2014). Literature review provides definitions of the concept from a wide range of disciplines under social, environmental and economic perspectives (Daunorienė et al., 2015; Puschmann and Alt, 2016; Belk, 2014; Allen and Berg, 2014), but overall, it represents a set of practices and models that, through technology and community, allow individuals and companies to share access to products, services, assets and experiences (Danourienė, 2015). Thus, the value of the concept is the creation of utility between the owner of a resource and clients that need that resource, enabling a flexible transaction at the adequate time and with a reasonable fee.

Although the boundaries of the sharing economy concept are still indeterminate - reflecting its evolutionary character and variety in scope - the growing concern about climate change and sustainability has made this emergent model an appealing path for achieving more sustainable cities (Allen and Berg, 2014; Daunorienė et al., 2015). Boosters claim that the sharing economy, supported by new technologies, will yield utopian sustainability benefits. The principle is that cities have many resources that can easily and effectively be redistributed. By allowing people to own less and consume only what they need, fewer resources are wasted, promoting urban sustainability.

Nevertheless, the positive potential attributed to the sharing economy to achieve urban sustainability, cities also face related unprecedented and complex questions of governance. The greatest challenge for cities is finding a balance between embracing the new businesses created within the context of a sharing economy and regulating the operational conditions in which sharing systems can lead to major benefits for residents and visitors.

Therefore, city leaders are being forced to address the rising popularity of new applications and services of a sharing economy in a role in which they are still inceptive. Municipalities are expected to act as intermediary, either by providing platforms for consumers to share goods and services, by providing additional value-added services (such as, insurance or payment services) or by regulating a more efficient use of public infrastructures. By serving as early boosters for the concept, municipalities can enhance its success (Belk, 2007; Daunorienė et al., 2015; Puschmann and Alt, 2016).

The application of the shared economy model to logistics highlights a paradigm shift in how the problem of accommodating urban logistics operations is now perceived and solutions are evaluated. The fundamental change is that the "predict and provide" planning, in which past trends were extrapolated to predict future demand are no longer adequate to support city planners. The new paradigm strives to use facilities efficiently and thus, considers too much supply as harmful as too little, and prices that are too low as harmful as those that are too high. Therefore, to promote an efficient use of resources, it is necessary to find an equilibrium between the usage of the facilities and their availability and costs. When thinking about how the new paradigm of increasing infrastructures efficiency is applied to accommodate urban logistics operations, it emerge strategies of sharing infrastructures like logistic hubs or parking regulations to prioritize previously dedicated infrastructure use. These strategies have positive impacts on land costs consumption, traffic volumes impacts as well as reduction of 10–30% on typical parking requirements reductions (Litman, 2006) and cost savings of up to 20% with shared infrastructure usage (Goyal et al., 2016), supporting the argument that a sharing model can promote urban sustainability.

This paper addresses the topic of shared usage of public infrastructures, in particular, shared parking facilities. Authors of this paper analyse the effect of implementing the shared parking usage by schools and colleges users and by logistic operators for loading/unloading activities. The following section presents this analysis and its effects in urban sustainability metrics.

3. Assessing the potential of sharing public infrastructures to pursue an urban sustainability path

Parking management strategies, such as shared parking, can mitigate the traffic congestion problems and respective delays and pollutant emissions generated by illegal parking incidents. In spite of the potential of sharing public infrastructures to attain a better level of sustainability, there is a lack of research in the public policy and management disciplines regarding factors influencing the adoption and success or failure of collaborations between the private sector and cities in solving urban sustainability challenges in the context of a sharing economy. In that perspective, this paper analyses if a shared parking solution leads to better environmental, energy and traffic performances as an urban sustainability measure. The solution consists on sharing parking spaces previously used exclusively by city logistic vehicles with other users. Once the peak demand hours of city logistics drivers and of parents dropping their kids to school are not coincident, the same reserved space can be used by both groups in different periods of the day without conflicts. Thus, one of the paper objectives is to assess if this type of sharing parking solution can improve the efficiency of the public infrastructure in terms of environmental, energy and traffic performance indicators.

To achieve this goal, the authors used a microscopic traffic simulation model developed with AIMSUN (Barceló, 2002) to build up different test scenarios where the efficiency of the shared parking solution could be quantified and evaluated. The model was built upon real experimental data of traffic counts and parking demand and allows incorporating the real-world road network with its physical intrinsic characteristics, as well as a detailed disaggregated typology of vehicles and respective associate emission, with the stakeholders' main parking purpose (private or commercial transport). Fig. 1 illustrates the methodological framework used in this study.

The methodology is based on real traffic data, collected to construct the microscopic traffic model which was calibrated and validated for the existing conditions (baseline scenario). Traffic performance is assessed using traffic parameters, taking into account traffic flows and parking patterns (legal and illegal) from counting surveys, the physical characteristics of the infrastructure, vehicle demand typologies (passenger vehicles, goods vehicles) and the vehicles' propulsion technologies (e.g. gasoline, diesel, LPG). The model provides the traffic data of the road network for the alternative scenario. This data is used as an input to the next step, which quantifies the amount of energy consumed
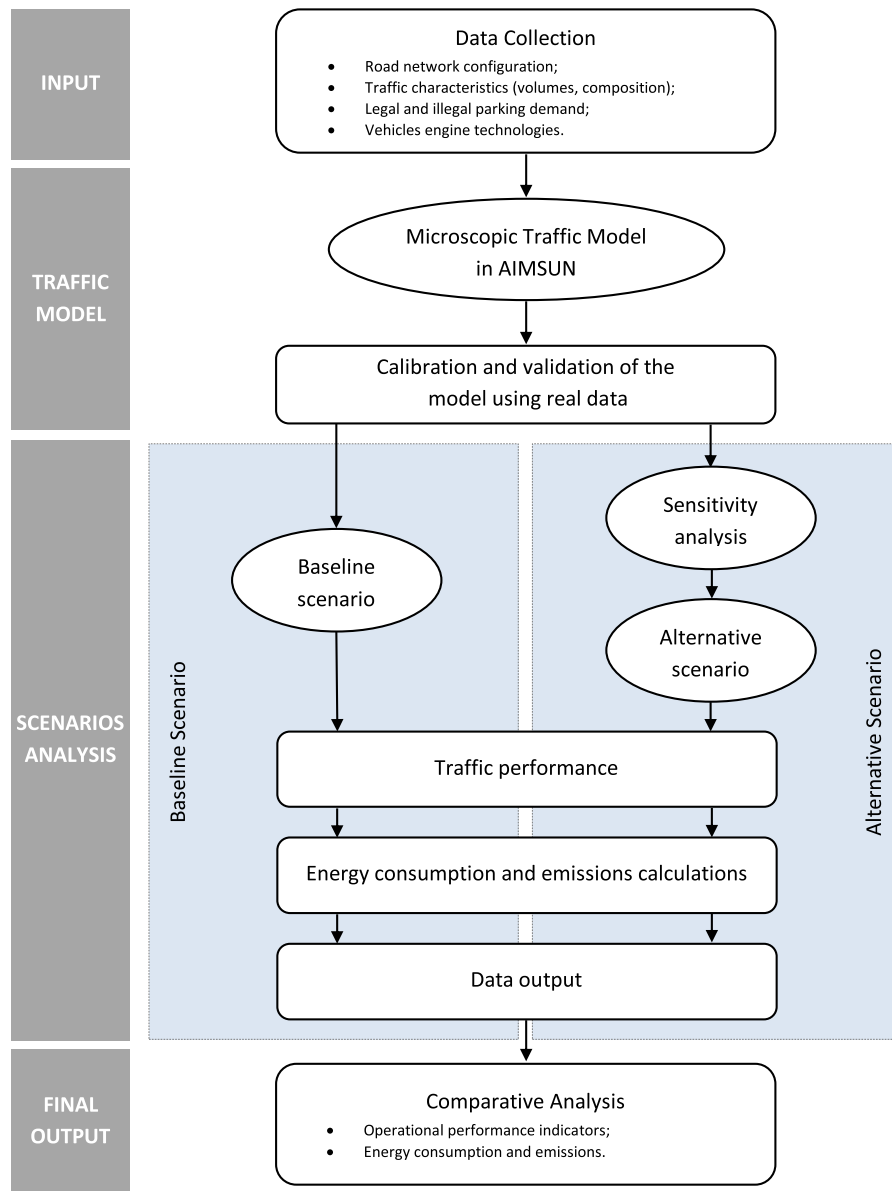
Fig. 1. Methodological framework.

for the alternative scenario in order to calculate the impact of the measure for various vehicle types. The final step is to perform a comparative analysis of the results and the efficiency of the solution is evaluated.

3.1. Traffic performance parameters

The analysis was carried out through the development of a microscopic traffic simulation model for a case study in a dense commercial area in Porto (Portugal). The commercial software adopted in the microsimulation exercise was AIMSUN version 8.1 (Lic IDMEC_160222). AIMSUN stands for Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks and is a microscopic traffic simulation tool that has been developed by Universidad Politecnica Catalunya and Transportation Simulation System of Barcelona, Spain (Barceló, 2002). The model was developed for being a traffic support tool for engineers with the objective of analyzing and designing traffic models. AIMSUN has proven to be useful in testing new traffic control systems and management policies based on traditional technologies, as well as in the

implementation of Intelligent Transport Systems (TSS, 2011). AIMSUN simulations can be classified as hybrid processes, combining an event approach with activity scanning. AIMSUN simulates the individual behavior of a vehicle on the network over time and in accordance to theories of vehicle behavior, namely the Gipps car-following (Gipps, 1981), lane-changing (Gipps, 1986) and gap acceptance models (Casas, 2010). This microscopic traffic simulator considers the changes in travel time along the day, as a result of variations in traveling speeds due to the variation in traffic density. As a consequence, the model identifies traffic congestion problems and allows exploring potential policies to deal with it. Moreover, it allows the assessment of transportation energy efficiency, in variables such as fuel consumption and emissions, since the measurement of fuel consumption and emissions is closely associated with the time-varying real-time speed in urban areas. AIMSUN also allows calculating fuel consumption levels at a second by second basis, which makes it possible to avoid the simplification of average values per kilometer. Further technical details about the AIMSUN and its capabilities can be found in Barceló (2002) and Casas (2010).
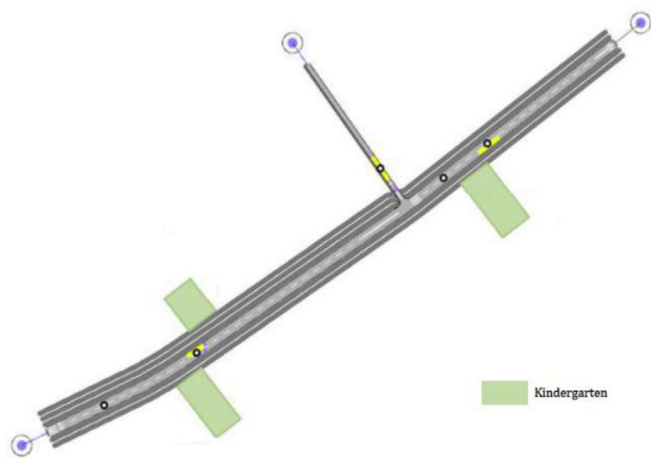
Fig. 2. Study area in Porto (Portugal).

Taking advantage of the AIMSUN potentialities, several studies on urban logistics and parking policies have been recently developed using this simulation tool (Barceló et al., 2007; Melo and Baptista, 2017; Melo et al., 2017; Costa et al., 2014; Aditjandra, 2016; Borovskoy, 2017; Melo, 2014). Considering the described above and the intention to study the impact of the shared parking in the traffic operation performance and transportation energy efficiency and the chosen microscopic traffic software, the authors developed the dynamic traffic simulation model to quantify traffic parameters as shown in Fig. 2.

The input demand of the model, namely traffic volumes and parking patterns, for private, public and freight transport were defined by real data, based on the survey performed by Costa (2016). The demand for parking was obtained by counting the number of vehicles that parked at the site, type of parking (legal and illegal) and its duration. The range of parcel sizes and weights makes it viable for all parcels to be delivered by the same light vehicle class as roughly 90% of the stores of the area receive a single parcel. The considered period for data collection to establish the parking demand pattern was between 7:30 and 12:00 on a typical week day, which include the morning rush hour, and was collected in March 2016. The geometric data of the public road infrastructure was provided by the Department of Mobility of the Municipality of Porto.

The simulation layout is a two-lane two-way road section with an extension long enough to accommodate lane changing and vehicle overtaking. The section is located in an historical building area and its layout cannot accommodate the creation of a kiss and ride area. The delay between simultaneous overtaking was adapted in AIMSUN from 10 s to 1 s to allow a closer real overtaking behavior, as performed in others studies (BRISA, 2017). In order to simulate double lane parking incidents, the traffic management policy action named "periodic section incident" was used. As observed in loco, the average length of each incident is of 5 m having 1 m of interval separating each incident. The "visibility distance" of the incident was considered to be of 50 m, which is more adequate for the local urban environment, and is in accordance to previous studies (BRISA, 2017). The bus stops were also simulated as well as bus parking occurrences. Traffic lights and pedestrian crossings were not included in the simulation, since these road elements are outside the area of analysis. The simulation was performed for the morning peak period and included the mentioned vehicle typologies.

The calibration of the model was based on the simulation results from a preliminary number of runs where the average sample and variance are used to obtain the Confidence Interval (CI) based on the t-distribution, as suggested by Hale (1997). Due to the stochastic nature of the microsimulation model, each scenario was run with 10 random seeds and the results were statistically analysed as recommended by Bloomberg (2000), Dowling, (2004) and McLeod (2009). Only the

simulation results that are statistically significant are presented (i.e. with a confidence level (CL) of at least 90%). In the validation step, the estimated traffic volumes, travel times and speed profiles were compared with the observed data collected by the GPX Viewer tool. For this comparison, two paths along the street were selected and 5 points were compared. To evaluate the goodness of fit, the GEH and the percent Root Mean Square Error (RMSE) between observed and estimated data were used. The results obtained shows GEH values less than 0,4 to all the points were the traffic volumes were compared and values of the percent Root Mean Square Error (RMSE) less than 8% in terms of travel times and speeds. After the calibration and validation were concluded, the model was prepared to simulate the effects of the BAU and of the alternative scenarios.

3.2. Energy and environmental impacts

Fuel consumption and CO_2 emissions were quantified based on the vehicles' operational performance including cruising, acceleration/deceleration, and idling periods. The energy consumption and emission factors are applied per driving situation/period, through the association of energy consumption and emission factors to each vehicle category, according to their speed and acceleration profiles, based on literature data (Panis, 2006). The spatially and temporally aggregation of all energy consumption and emissions impacts is performed in order to obtain an overall trip assessment. The outputs retrieved from simulation were: vehicle flow, delay time, speed, mean queue size, fuel consumption, and pollutant emissions (CO_2, NO_X, PM and VOC). Flow, delay time, speed and mean queue indicators were obtained for the lane subjected to double parking, while fuel consumption and pollutant emissions refer to the analysed road section considering both lanes.

In some regions, road gradient plays an important role and can result in higher CO_2 emissions. The area of the case study presents a road gradient lower than 1% and the average distance performed by a vehicle within the network is shorter than 1 km, which is not relevant for the spatial reference of analysis in terms of environmental effects when applying calculations referred by Demir et al. (2014). Therefore, road gradient was not included in the environmental modelling.

3.3. Definition of scenarios and experimental design

The study area is a segment of Costa Cabral Street, located in the city of Porto, Portugal (Fig. 2). Costa Cabral is a two-direction carriageway with a total width of 9 m (between curbsides), with sidewalks in both sides of the street and on-street parking. Currently, the road infrastructure has a parking area with 10 places exclusively dedicated for city logistic operations and the remaining 31 places are used for any type of vehicles, free of charge and without a time limit for that use as shown in Fig. 3.

Due to the high demand for parking in an area with a dominant use of commerce and services as well as kindergartens and schools, it is possible to observe a significant number of illegally parked vehicles. Traffic demand revealed that a total of 1930 vehicles per hour enter the network in the morning peak (7:30–9:30), of which 86% are private passenger vehicles, 8% are commercial heavy vehicles and 6% are buses. Data from parking demand shows that from those vehicles accessing the network, there was one vehicle parking in the area of study at each 51 seconds. 26% of the vehicles parked legally with an average parking time of 74 min. The reminder 74% parked illegally of which 13% chose to do it in double lane and 61% chose the spaces dedicated to freight vehicles or private garage entrances. Vehicles parked in double lane take an average parking time of 5 min while private passengers' vehicles that chose to use illegally the space dedicated to urban logistics operations take an average parking time of 23 min. Buses parked for periods shorter than 1 min.

These characteristics make this street segment the ideal site for the study of strategies to potentially improve the sustainability of the area,
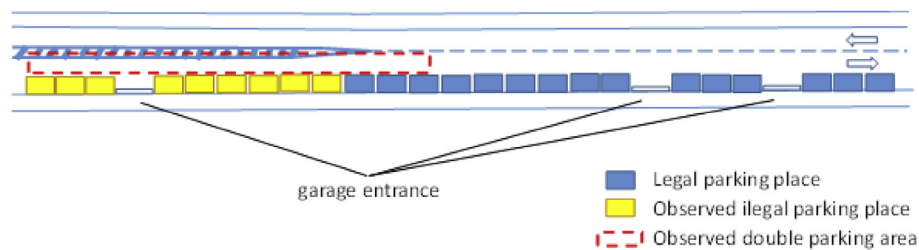
Fig. 3. Examples of legal and illegal parking places at a segment of the study area.
Source: BRISA, 2017

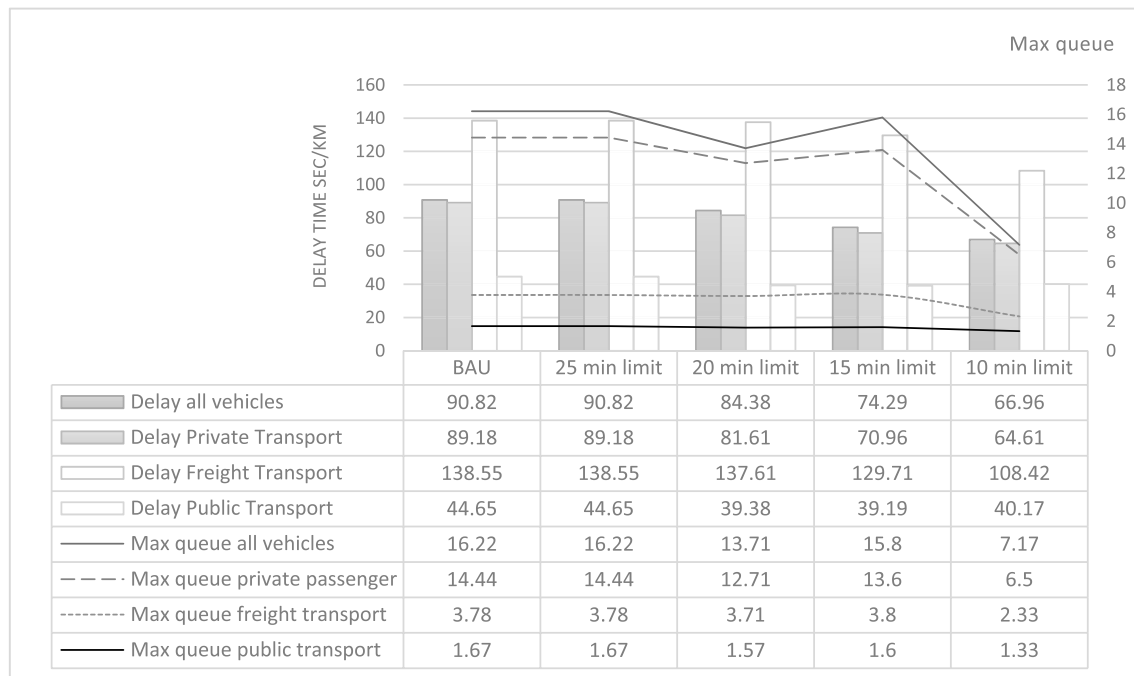|	BAU	25 min limit	20 min limit	15 min limit	10 min limit
Delay all vehicles	90.82	90.82	84.38	74.29	66.96
Delay Private Transport	89.18	89.18	81.61	70.96	64.61
Delay Freight Transport	138.55	138.55	137.61	129.71	108.42
Delay Public Transport	44.65	44.65	39.38	39.19	40.17
Max queue all vehicles	16.22	16.22	13.71	15.8	7.17
Max queue private passenger	14.44	14.44	12.71	13.6	6.5
Max queue freight transport	3.78	3.78	3.71	3.8	2.33
Max queue public transport	1.67	1.67	1.57	1.6	1.33

Fig. 4. Sensitivity analysis to define the maximum parking time limit for the shared parking places.

through solutions such as the introduction of shared parking. Under these conditions, the baseline scenario represents the actual traffic and parking conditions at the site and the model assess the potential of sharing the infrastructure to attain a less congested and polluted street. The scenario to be tested does not assure the current exclusive use to city logistic vehicles, but rather shares those places of the public infrastructure with parking demand allocated to kindergartens, for limited periods of time per operation. Once the peak demand hours of city logistics drivers and parents is not coincident, sharing the same reserved space improves the efficiency of the use of the public infrastructure and minimize its environment burden. The principle is that municipalities can manage their infrastructure in a more effective way, which can lead to lower environmental and congestion impacts in the city.

First, a sensitivity analysis is performed to establish a limit of time to be imposed to those shared spaces, dependent of other traffic parameters. For that were considered four different limits of time, 10, 15, 20 and 25 min. In a second step, and considering the output from the sensitivity analysis, a comparison is made between the baseline scenario and the shared infrastructure scenario.

3.4. Assessing the minimum time limit for short term parking

The study area has a high demand for parking by users of kindergartens and commerce. If the municipality would promote sharing the public infrastructure among those users, traffic performance could improve. With this base idea a sensitivity analysis was carried out to define the maximum parking time limit for the shared logistics and school places.

The first task was defining the upper and lower limits for that time based on real data. Parking surveys performed by the authors in Costa (2016), show that the parking occurrences have an average duration of 6 min and 78% of them register parking times shorter than 25 min. The high frequency of the parking events with durations below 25 min (short time parking) highly disturbs traffic flow as mostly of them occur illegally in double lane. The surveys also revealed that parking occurrences taking more than 25 min are already currently allocated to legal parking places in the street. Based on these arguments the authors chose the maximum limit of time per parking of 25 min.

Furthermore, parents need a minimum of time to park the vehicle and take the children to the school, plus the walking time from parking place to the school. In the same way, commercial vehicles drivers also need a minimum of time to park the vehicles and take the load to the store, plus the walking time from parking to the store. As the parcel sizes and weights are typically low, there is no need to perform a time sensitivity analysis based on the type and size of goods delivered in the area. For these reasons, authors chose that the minimum limit to be considered as a threshold in the sensitivity analysis could not be lower than 10 min. The sensitivity analysis was then performed for 10, 15, 20 and 25 min in order to define which of those limits would be the best one in terms of traffic performance to establish the use of the shared places between commerce and kindergarten users. To compare the

traffic performance achieved for the different parking time limits tested, it were used as performance indicators the delay time and the maximum queue.

Fig. 4 summarizes the variation of delay times (bars) and maximum queue (lines) by type of vehicle for each of the parking limits considered for the analysis.

Comparing the traffic metrics for the BAU scenario with the scenario of allowing kindergarten and city logistics users to share the same dedicated places for periods up to 25 min, the traffic performance of the network is not affected. The explanation for this fact is that most of the legal parking takes more than 25 min and therefore, establishing a limit of 25 min does not have a direct influence in minimizing the illegal parking in the area.

Reducing the parking limit to 20 min would bring positive effects mostly to private passenger and public transport vehicles. Freight transport vehicles currently take an average of 13 min to park in their exclusive places and therefore would not significantly be affected by a limit of 20 min.

The improvements in the traffic performance within the network are actually felt in a more significant way for all users, when that time limit is lower than 15 min and the best results are achieved with a 10 min limit. With a parking limit of 10 min for the usage of the current exclusive logistics parking with schools users, delays would be reduce by 26% reaching the 67 s/km and the queue would be reduced up to 56% to a maximum of 7 vehicles in queue. These positive results would be felt by passenger vehicles, commercial vehicles and buses. Delay times for private and commercial vehicles would be reduced by 28 and 22% while the queues would be reduced by 55% and 38%.

The positive results consistently obtained with the implementation of parking time limits reach the best traffic performance with a 10 min limit for the shared parking usage, felt by all the typologies of vehicles. Considering the limit obtained from the sensitivity analysis, the following section compares both scenarios in terms of traffic performance, environment and pollutant emissions as metrics of the local urban sustainability.

4. Results and discussion

The study intended to analyse if the implementation of a solution that aims to promote a more efficient usage of a public infrastructure – shared parking – can contribute to improve the local urban sustainability. The chosen solution to be tested consists on the shared usage of parking areas that are currently dedicated to be exclusively used for city logistics operations. Those parking places would be used either by the logistic operators or by kindergarten users for a limited period of time. Thus, during the periods of the day that the parents need to leave or pick up the children the places will be available to these users. Outside these periods the parking places are intended to city logistics operations. The urban sustainability will be assessed through traffic performance indicators (delay, mean speed, travel time, stopped time and the average queue length) and environmental indicators (fuel consumption and pollutants emissions). The comparison between the scenarios is presented in Figs. 5 and 6.

Results reveal that if the municipality would implement the shared usage of the current exclusive places for urban logistics operations, private, freight and public transport would experience a decrease in delays and improvements in their speeds, which means that it would lead to improvements in the traffic performance network. In spite of the fact that along the baseline scenario, urban logistics vehicles have the exclusive usage of a number of on-street parking places that are considered to be shared with school users (who have different peak hours), commercial vehicles experience a decrease on delays by 22% and an improvement on speed by 1%. Results illustrated in Fig. 6 also corroborate these findings as all vehicles experience a decrease in their travel

time and in the time they are stopped in the traffic. The travel time is reduced on average by 11% within the network, but commercial vehicles are the ones experiencing the highest reduction (−13%) registering a travel time of 195 s/km. Private passenger vehicles also register an average decrease in the time they are stopped by 31%, while commercial vehicles experience reductions by 27% corresponding to 85 s/km. The variations illustrated in both figures take into account all commercial vehicles moving within the network and not only the ones who park in those places. Therefore, the positive benefits that are experienced by all the typologies of vehicles, and in particular by commercial vehicles, result from the fact that a) the public parking infrastructure is managed in a more efficient way that promotes the turnover and b) the increasing of the parking turnover and the permission for kindergarten users to park in those places is reflected by a decrease in the illegal double parking, which generally improves the traffic performance within the network. One obvious observation of that improvement is illustrated in Fig. 7, where it is possible to perceive the variation of the length of the queues created during the parking maneuvers. The average queue length decreases by 32%, with the highest reduction being registered in the private passenger vehicles (34%), once the traffic streams in the network are composed by 83% of this type of vehicle.

The coherence of the tendencies observed for the traffic indicators demonstrates the expected positive impact of shared parking for urban logistics and school users, with a pre-defined limit of parking time.

The following step to assess the local urban sustainability is to confirm that additionally to the traffic improvements, the solution also leads to energy and environmental benefits. As presented in Fig. 8, the overall fuel consumption would be reduced up to 4.7% (for the 10 min limit scenario). This reduction if justified not only by a 1.5% decrease in the number of vehicles entering the area, but also by an improvement in energy efficiency, since vehicle fuel efficiency performance also improves (with a 4.2% reduction). It is worth noting that it is for the private passenger cars and freight transport vehicles that the improvements are higher, meaning that there are no trade-off effects between them that result from the adoption of this shared parking solution.

Additionally, the implementation of this solution also affects local emissions, as presented in Table 1. For the sharing scenario with a parking time limited to 10 min, reductions of 3.7% for CO_2, 6.4% for NO_x, 3.2% for PM and 7.6% for VOC are obtained. At urban level, these reductions are significant and imply lower exposure risk to local pollutants, with consequent health and quality of life benefits.

After this scientific study was carried out, the municipality performed a practical implementation of the initiative. The practical results are in line with the ones predicted by this study.

5. Conclusions and future research

The paper analysed the impacts of promoting the shared usage of logistic parking infrastructure owned by public authorities, specifically the share of previously dedicated parking spaces for city logistic vehicles with other users that use the infrastructure in different periods of the day, in this particular case with the vehicles of parents leaving or picking up their children from neighbouring kindergartens or schools. The effects were quantified in metrics of transport performance, energy and environmental criteria. The scenario was compared to a baseline situation and results show significant reductions in delay times, travel times, queue lengths and stopped times and increases in average speeds. Also, fuel consumption and emissions present considerable reductions in the tested scenario (of up to 16 kg of CO_2 emissions and 0.186 kg of local pollutants per day). As a result, the paper concludes that municipalities can take advantage of a sharing economy context, by using their assets in a shared and more effective way to attain a more
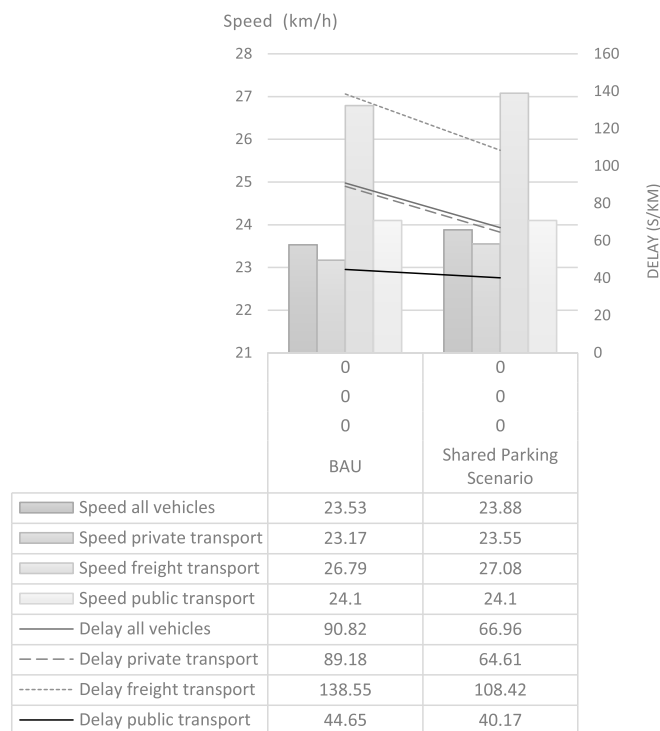
Speed (km/h)

	BAU	Shared Parking Scenario
Speed all vehicles	23.53	23.88
Speed private transport	23.17	23.55
Speed freight transport	26.79	27.08
Speed public transport	24.1	24.1
Delay all vehicles	90.82	66.96
Delay private transport	89.18	64.61
Delay freight transport	138.55	108.42
Delay public transport	44.65	40.17

Fig. 5. Delay time and speed variations in the overall network.

sustainable city. Those benefits are translated into the reduction of externalities and improvement of the quality of life in the city and therefore, municipalities benefit from playing an active role in the emergent context of a sharing economy. Although these benefits can represent an upper bound of sorts, since the case study site is located in a favourable area of the city with a significant number of education facilities and commercial stores, the study demonstrated the potential of this type of solution which was corroborated by the practical implementation meanwhile carried out by the municipality.

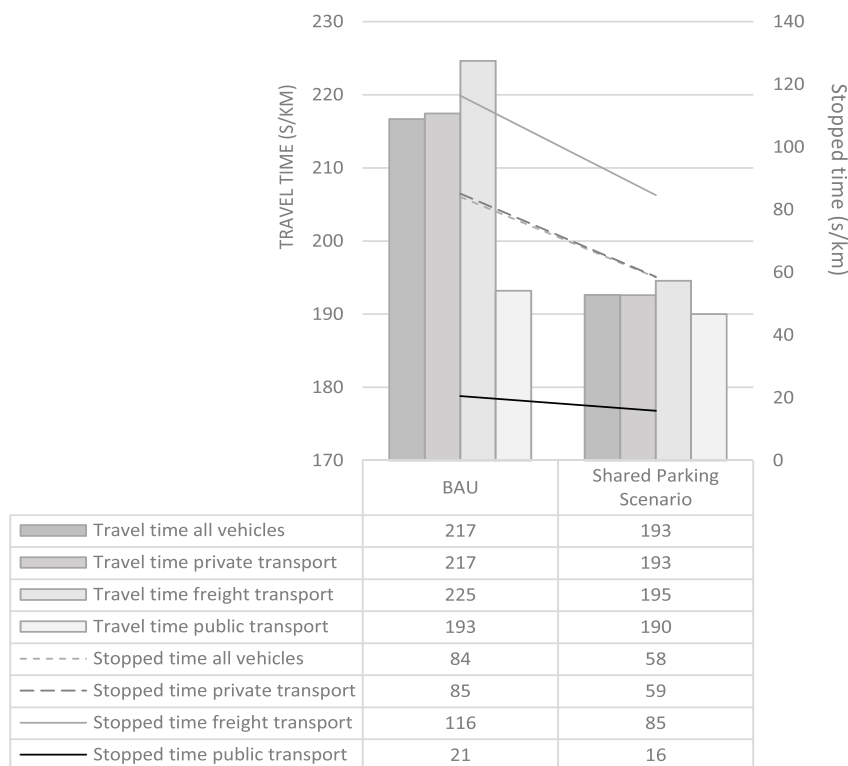Moreover, results demonstrated that in spite what could be seen at

	BAU	Shared Parking Scenario
Travel time all vehicles	217	193
Travel time private transport	217	193
Travel time freight transport	225	195
Travel time public transport	193	190
Stopped time all vehicles	84	58
Stopped time private transport	85	59
Stopped time freight transport	116	85
Stopped time public transport	21	16

Fig. 6. Travel and Stopped time variations in the overall network.
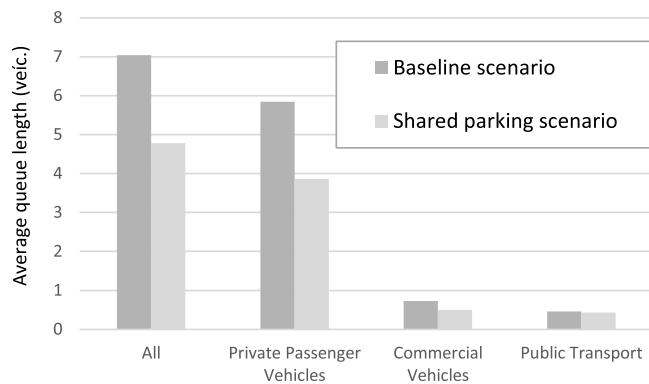
Fig. 7. Average queue length variations in the overall network.

Table 1
Emissions (kg) results for the considered scenarios.

Total emissions	Baseline Scenario	Shared Parking Scenario	Variation (%)
CO_2	432	416	−3.7
NOx	2.35	2.20	−6.4
PM	0.125	0.121	−3.2
VOC	0.421	0.389	−7.6

first sight as a loss of exclusivity and privileges by freight transport, there are similar benefits for private passenger vehicles and commercial vehicles, which reveals the wide range of users that can benefit with implementing a shared logistics parking infrastructure owned by public authorities. Additionally to the quantified effects, it is also important to mention that there are also social and economic benefits for the area that result from the direct traffic and environment effects. Municipalities should consider that playing an active role in the current context of a sharing economy, by making the use of their assets more efficient can yield enormous gains in urban sustainability levels. The implementation requires a close dialogue with other stakeholders involved, namely freight operators. The result of this dialogue will be reflected by adequate parking regulation that control who, when and

how long vehicles may park at a particular location, specifying the user or vehicle type to prioritize, the respective time limit and eventual time period restrictions (night use, etc.). In the case study described along the paper all vehicle typologies would benefit from the solution.

For an implementation of such type of solution, the role of municipal stakeholders would be decisive in the adequate design, implementation and communication of a shared parking infrastructure. As proven by the adoption of other transport solutions, proper enforcement must be imposed by the authorities to guarantee the right use of the urban space mostly in terms purpose, limit duration and time period. Nonetheless, these municipal efforts would result in effective benefits by the reduction of externalities and improvement of the quality of life in the city. Therefore, municipalities would gain from playing an active role in the emergent context of a sharing economy. Although the case study described on this paper cannot be generalized on its essence, it demonstrates that there is room for municipalities to explore shared solutions that distribute resources in a more effective way and can, consequently, yield major sustainability benefits.
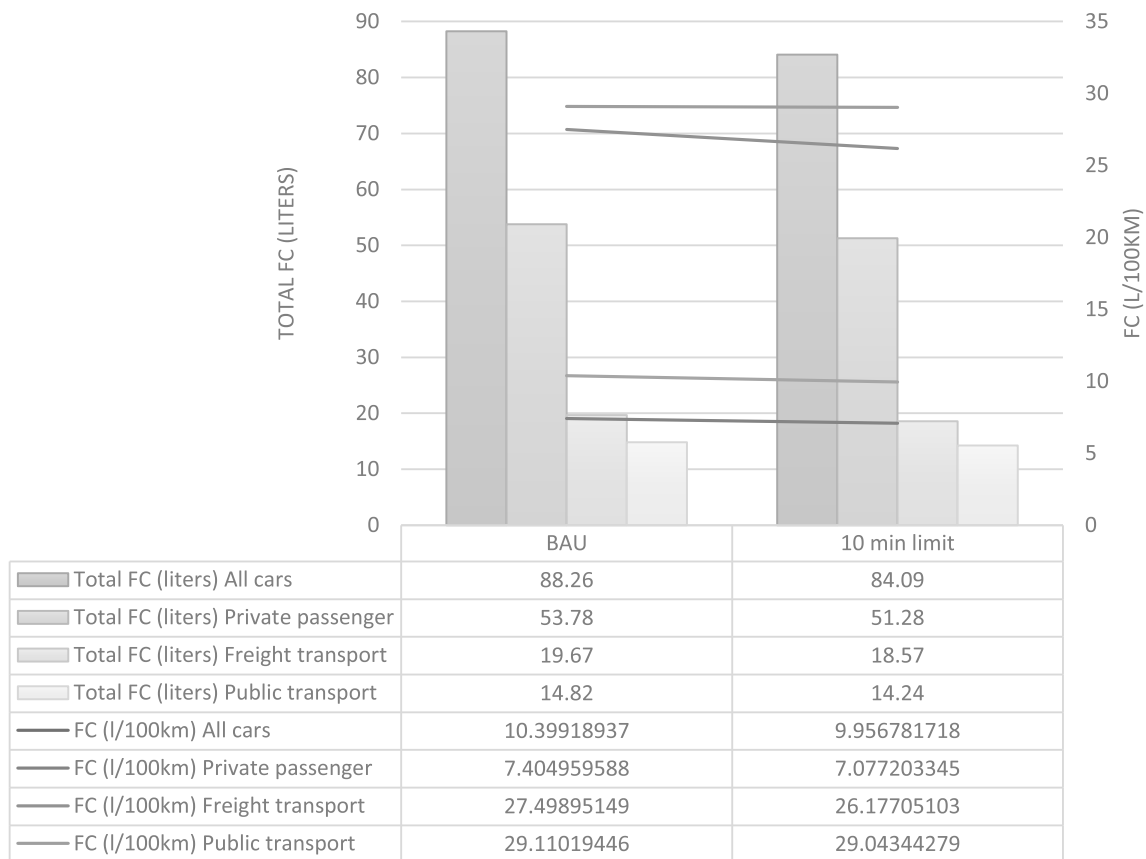

	BAU	10 min limit
Total FC (liters) All cars	88.26	84.09
Total FC (liters) Private passenger	53.78	51.28
Total FC (liters) Freight transport	19.67	18.57
Total FC (liters) Public transport	14.82	14.24
FC (l/100km) All cars	10.39918937	9.956781718
FC (l/100km) Private passenger	7.404959588	7.077203345
FC (l/100km) Freight transport	27.49895149	26.17705103
FC (l/100km) Public transport	29.11019446	29.04344279

Fig. 8. Fuel consumption (liters and l/100 km) variation.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.tranpol.2018.07.003.

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